Collaboration and Coalition Architectures[1]

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Abstract

When command centers from multiple organizations join together to form a coalition, different task assignment strategies can be used to determine what tasks each cooperating command center should participate in. As the composition of a coalition may change over time, i.e. new organizations may join after the initial coalition has been formed, and some organizations may leave before the mission is accomplished, the allocation of the coalition's systems to mission tasks becomes an important aspect of the coalition, as it may change dynamically. The way in which tasks are assigned to the cooperating command centers creates different coalition architectures, which induce different levels of collaboration requirements among the cooperating command centers. The mission may be defined so that the tasks can be divided into geographic sectors with a responsible cooperating command center for each sector; this results in a divisional structure, which requires a low level of collaboration among the cooperating command centers. If the tasks are assigned based on each cooperating command center's ability to perform the task, this results in a functional structure, which requires a higher level of collaboration among the cooperating command centers to complete the mission. Using an executable model of a coalition, based on the model of the five-stage interacting decision maker, simulations were conducted that compared different methods of assigning systems to tasks in a coalition operation. The model was populated with data from an operational scenario that has been created to provide a context for development of coalition decision support system tools. The effect of the different operational architectures, based on the task assignment strategy, is reflected in the levels of collaboration required among the cooperating command centers, and the timeliness and accuracy of the coalition performance.

1.0 Introduction

One of the most critical dimensions of organizational architectures is departmentation, which refers to the degree to which systems are grouped based upon functional similarity or on geographic dispersion [Moon, et al, 2000]. Organizational architectures that employ functional departmentation tend to promote efficiency because it is easier to manage units which are performing similar tasks, redundancy is minimized, and high levels of functional expertise can be developed within the highly focused and specialized units. Functional structures usually have relatively high levels of centralization because individual units in the structures are so specialized that members of the units may have a weak

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conceptualization of the overall mission. On the other hand, divisional structures tend to promote flexibility because the units have broader capacities, i.e., they are less specialized and their regional focus helps them react more quickly to local threats. Divisional structures tend not to be very efficient, however, because there is often a great deal of redundancy among the broader subunits. Divisional structures have relatively low levels of centralization. Units in these structures act almost like separate, self-sufficient, semi autonomous organizations [Hollenbeck, et. al, 1999].

The choice between functional versus divisional structures is driven by the need for efficiency versus the need for flexibility. However, in a coalition environment there may be other factors, including the degree of collaboration desired or required. For example, functional architectures emphasize interdependent actions, and require a high level of communication, or collaboration, in order to achieve the mission. Bares [2000] described a cooperative framework for systems in a coalition that is characterized by the ability of every system in the coalition to assess its own competence on actions within the coalition; the cooperating command centers assess which of their systems are able to interact on what functional areas or tasks, and which particular systems are capable to carry out particular actions that compose the tasks of the coalition mission. Assigning systems from cooperating command centers to tasks based on assessment leads to a much more integrated, heterogeneous functional architecture that relies on the interoperability and cooperation between different systems on an operational level. In this case, a single command center must have the resources available to handle multiple occurrences of the task throughout the Joint Area of Operations (JOA).

Divisional architectures, on the other hand, emphasize independent actions and problem solving, with a lower level of communication, or collaboration. Every military unit has an Area of Responsibility (AOR) or real estate it controls by presence, force, and or legal authority; on a map, a geographic sector may be assigned to a unit or set of units to be their AOR [Henry, 2001]. By using geographic sectors, a less integrated, more autonomous divisional architecture is created that requires collaboration between the diverse systems only on a strategic level. This is appropriate when the cooperating command centers prefer to operate independently and the troop strength of each cooperating command center is such that it can provide the variety of skills necessary for the range of tasks that might occur within its AOR.

As each coalition operation is different, the resulting organizational architecture can be unique in both its structure and the processes contrived to satisfy the general principles for a successful mission. An architecture can also be created that attempts to use aspects of both functional and divisional structures. It is often the case in a coalition that one cooperating command center is much larger than the others. In this case the use of sectors can be complimented by assigning specialized tasks to a particular system across all sectors. This allows smaller collaborating command centers to still maintain a sector and yet shed tasks that are outside its capabilities. This hybrid architecture is hypothesized to result in the best performance.

2.0 Model Simulations and Results

Models can be used to test hypotheses about the behavior of different coalition architectures. A model of a coalition has been developed to evaluate the effect of different attributes of coalition architectures on coalition performance. The model represents a template for the coalition design and can be populated with data from different coalition architectures in order to evaluate different aspects of coalition operations.

In order to evaluate the impact of the task assignment strategy on coalition performance, a series of simulations were conducted. An experimental design was created to stimulate the coalition model with a set of tasks, each composed of a series of subtasks, which were completed by different coalition systems. The tasks were assigned to the coalition systems by three different methods, resulting in three different coalition architectures. The data used to populate the coalition model and the task graphs used to create the input scenario were extrapolated from a scenario currently being used for coalition research.

The task assignment strategies were implemented by using three different modes in the model. In the first mode, subtasks were assigned to the system responsible for the geographical sector that contained the task, regardless of any other task requirements; this resulted in a divisional architecture that required a lower level of collaboration between the systems. The second mode was by system self-assessment, the Bares' formalism. The subtask was assigned to the system that indicated it could perform it. This resulted in a functional architecture and required more collaboration among the systems. The third mode was a combination of both system self-assessment and geographic location, the hybrid architecture. The system responsible for the geographic sector of the task was first identified; if it had the capability for that task then it was assigned to that system. If the system responsible for the geographic sector did not have the capability on the task, it was assigned to an alternative system that could perform the task This hybrid architecture assigns a different system to specialized tasks within a geographic sector when the responsible system is lacking the capability on that task.

The coalition's performance was then evaluated under all modes by monitoring the accuracy and timeliness of the coalition's response to the tasks in order to evaluate the coalition's output as a function of task assignment strategy and the resulting architecture. Timeliness expresses the coalition's ability to respond to an incoming task within an allotted time. The allotted time is the time interval over which the output produced by the coalition is effective in its environment. Similarly, accuracy expresses a coalition's ability to make a correct response to an incoming task. The accuracy for each task can be described as an interval that contains the correct or predicted response plus or minus a margin of error within which the response is still acceptable.

The coalition operating under the third mode, task assignment based on both geographic sectors and system self-assessment was hypothesized to out perform the other modes. When a system performs a subtask outside its current geographic location, the task incurs a delay. When a system performs a subtask without the required capability, the accuracy of the task decreases. Task assignments based on geography are predicted to be timely but less accurate; this divisional architecture represents maximum duplication of effort, but minimum integration of coalition partners within sectors. Assignments based on system

self-assessment are predicted to be accurate but less timely; this functional architecture represents a more integrated approach, with all partners present in all sectors, but at the cost of a dispersed effort.

Figure 1 shows the results of the model simulations. The use of sectors (divisional) had the best timeliness score but the worst accuracy; this is due to the fact that in many cases the system responsible for the sector was not capable on the individual subtasks. System self assessment (functional) on the other hand, had the best accuracy score, but the worst timeliness score due to similar reasons: the subtask was assigned to a system not in the same sector as the task. The combined method (hybrid) received the most balanced scores as it tried to offset the effect of assigning a system to a subtask it was not capable on by assigning it to a system outside the sector (improving accuracy) and choosing the capable system within the tasks geographic sector whenever possible (improving timeliness).

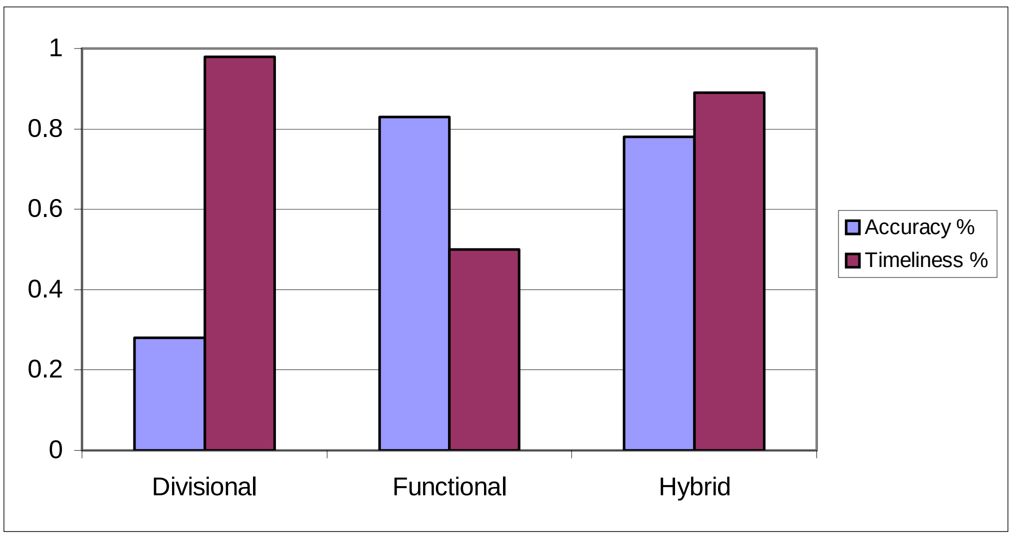

Figure 1: Model Simulation Results

3.0 Conclusion

An executable model was used to study coalition behavior under different architectures resulting from task assignment strategy. The different architectures also induced different levels of collaboration between the cooperating command centers. The results of this research indicate that task assignment strategy is an important aspect in improving coalition performance, however, traditional schemes may not always be optimal in coalition operations. In this particular scenario, all sectors were of equal size, regardless of the size or abilities of the participating command centers. In this case, one contingent was so much larger than the other two that it had two advantages: it included specialized units that were the only ones available to operate on specialized tasks, and it could handle a larger sector more efficiently than the other command centers. In future coalition operations it may be more appropriate to adjust the sector size proportionally to troop strength and specialties in order to achieve a balance across the participating organizations.

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Collaboration and Coalition Architectures

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TC3 Workshop:

Cognitive Elements of Effective Collaboration

Introduction

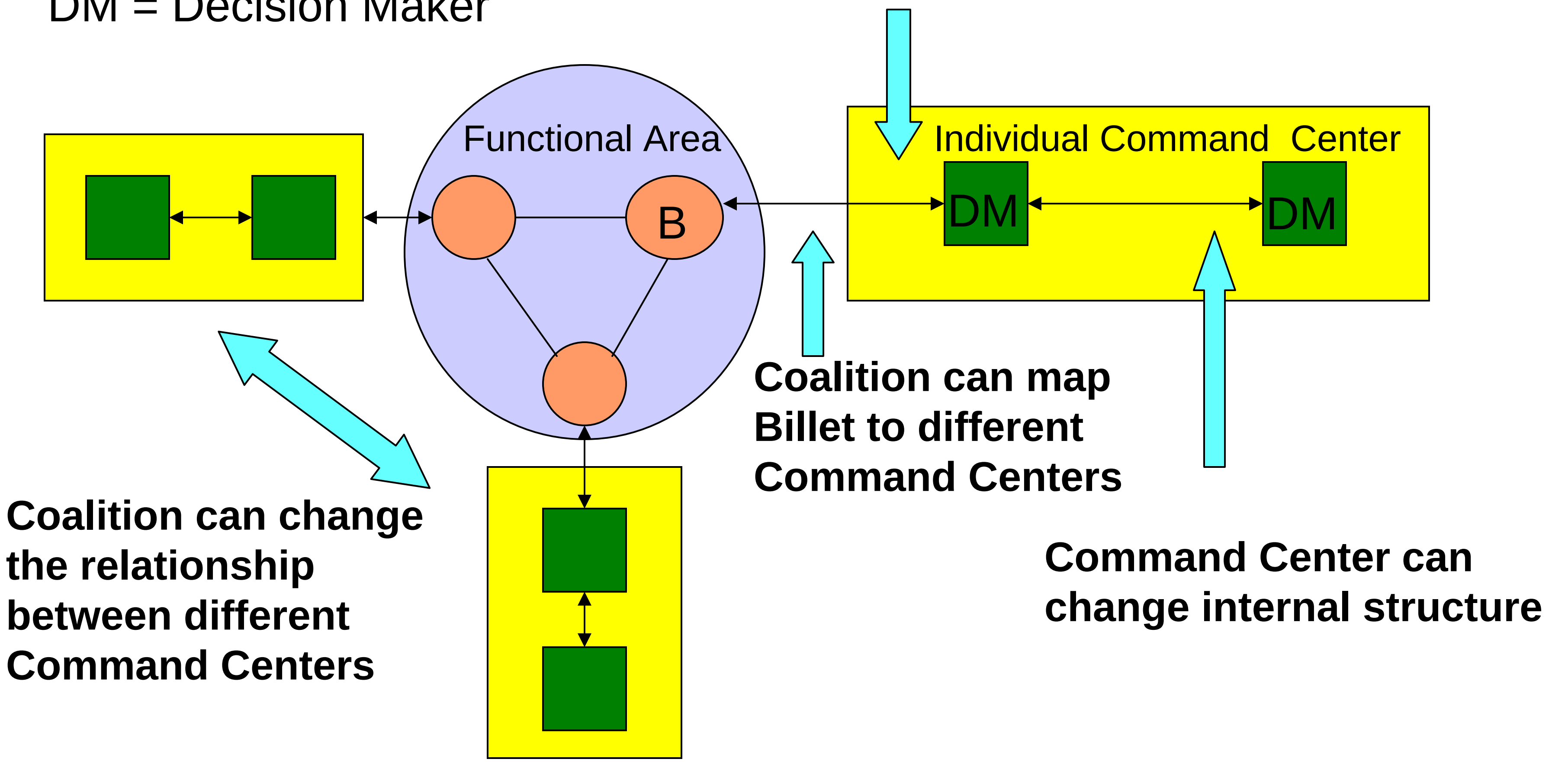
- Coalitions are composed of cooperating command centers which may have systems of different capabilities.
- Different task assignment strategies can be used to assign coalition tasks to the participating command centers' systems.
- The different strategies result in different coalition architectures
  - may induce different levels of collaboration among the cooperating command centers,
  - may result in different levels of coalition performance.

Adaptive Heterogeneous Command Centers

- The composition of a coalition may change over time
  - New organizations may join after the initial coalition has been formed and some organizations may leave before the coalition's mission is accomplished.
- A model of a coalition with a dynamic architecture
  - Interactions affected by parameters of heterogeneity,
  - Structure affected by different task assignment strategies.

Adaptive Heterogeneous Command Centers

B = Billet
DM = Decision Maker



Coalition Architectures

- Functional – tasks assigned by functional capability; the same system will perform single task type throughout the Joint Area of Operations.
  - Efficient – redundancy is minimized
  - Narrow focus leads to expertise
  - High level of centralization (weak concept of overall mission)
- Divisional – tasks are assigned by geographic sector; the same system will do all task types in an assigned Area of Responsibility.
  - Flexible – broader capabilities
  - Regional focus leads to quick reaction time
  - Low levels of centralization (autonomous units)

Functional Architecture

- Task Assignment Strategy = System Self Assessment
  - Tasks are assigned based on each system in the coalition's assessment of its functional capabilities.
  - Leads to an integrated coalition structure with cooperation between different systems on an operation level.
  - Each command center present in each sector – dispersed effort.
- Emphasizes interdependent actions and requires a high level of communication (collaboration).
- A system must have the resources to handle multiple occurrences of the task through out the Joint Area of Operations.

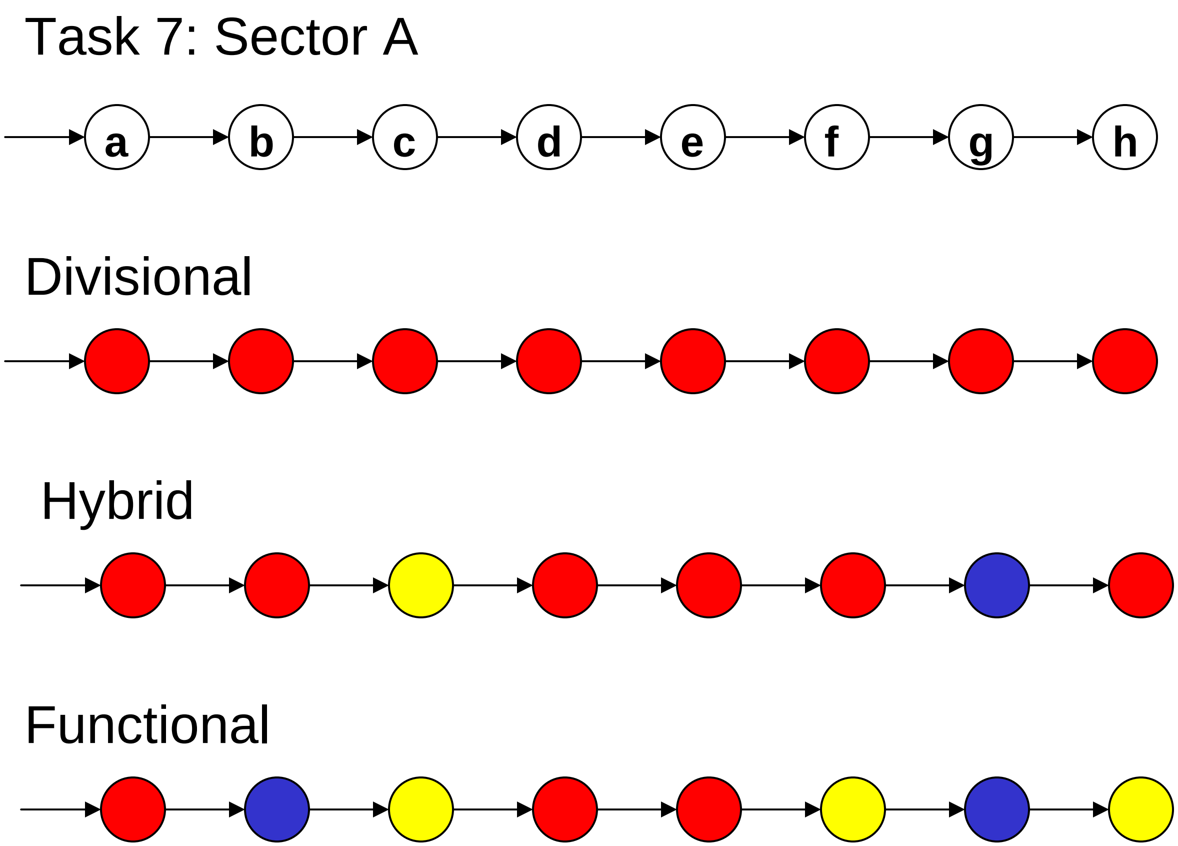
Divisional Architecture

- Task Assignment Strategy = Geographic Sectors
  - A geographic sector is assigned to a system to be its Area of Responsibility.
  - Leads to a more autonomous coalition structure with minimum integration and cooperation between different systems only on a strategic level.
  - Maximum duplication of effort.
- Emphasizes independent actions; appropriate when the cooperating command centers prefer to operate independently.
- A system must have the diverse capabilities required to handle multiple types of tasks throughout its Area of Responsibility.

Hybrid Architecture

- As each coalition environment is unique, architectures designed for specific coalition missions may also be unique.
- A hybrid architecture can be created that uses aspects of both the functional and divisional architectures
  - Based on the use of geographic sectors,
  - Certain specialized tasks are assigned to a specific system to complete across all sectors.
- Appropriate when one participating command center is much larger than the others – or when one or more participating command center lacks certain capabilities.

Collaboration vs. Architecture



Divisional	Functional
Controls all tasks in one sector	Controls all of one type of task
Generalized Knowledge	Specialized Knowledge
Multiple Resources	Single Resource
Independent	Interdependent
Local Communication	Global Communication

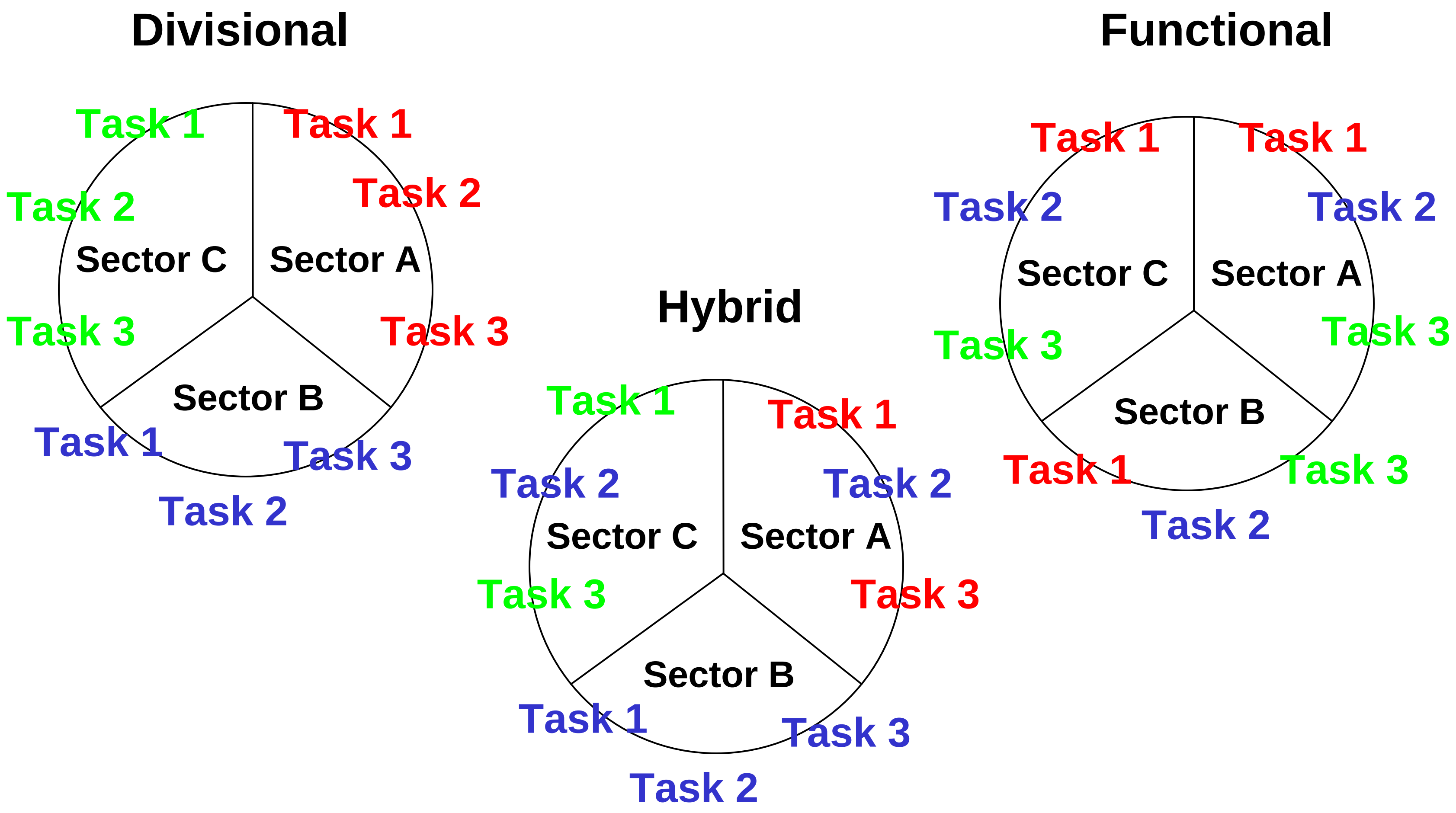
The Coalition Model

- A model of a coalition has been developed in order to test hypotheses about the behavior of different coalition architectures.
- Colored Petri nets were used to create an executable model which can be used to evaluate coalition performance.
- The model represents a template for the coalition design which can be populated with data from different coalition architectures in order to evaluate different aspects of coalition operations.
  – Three cooperating command centers (systems)
  – Three geographic sectors.
  – Five tasks with multiple subtasks occurring in each of the three sectors.

Task Assignment Strategies

- Method 1: Tasks were assigned to the system responsible for the geographic area in which the task occurred.
  - Divisional Architecture
- Method 2: Tasks were assigned to the system that had functional capability on the type of task.
  - Functional Architecture
- Method 3: Tasks were first assigned based on geographic area and secondly on functional capability.
  - Hybrid Architecture

Task Assignment Strategies



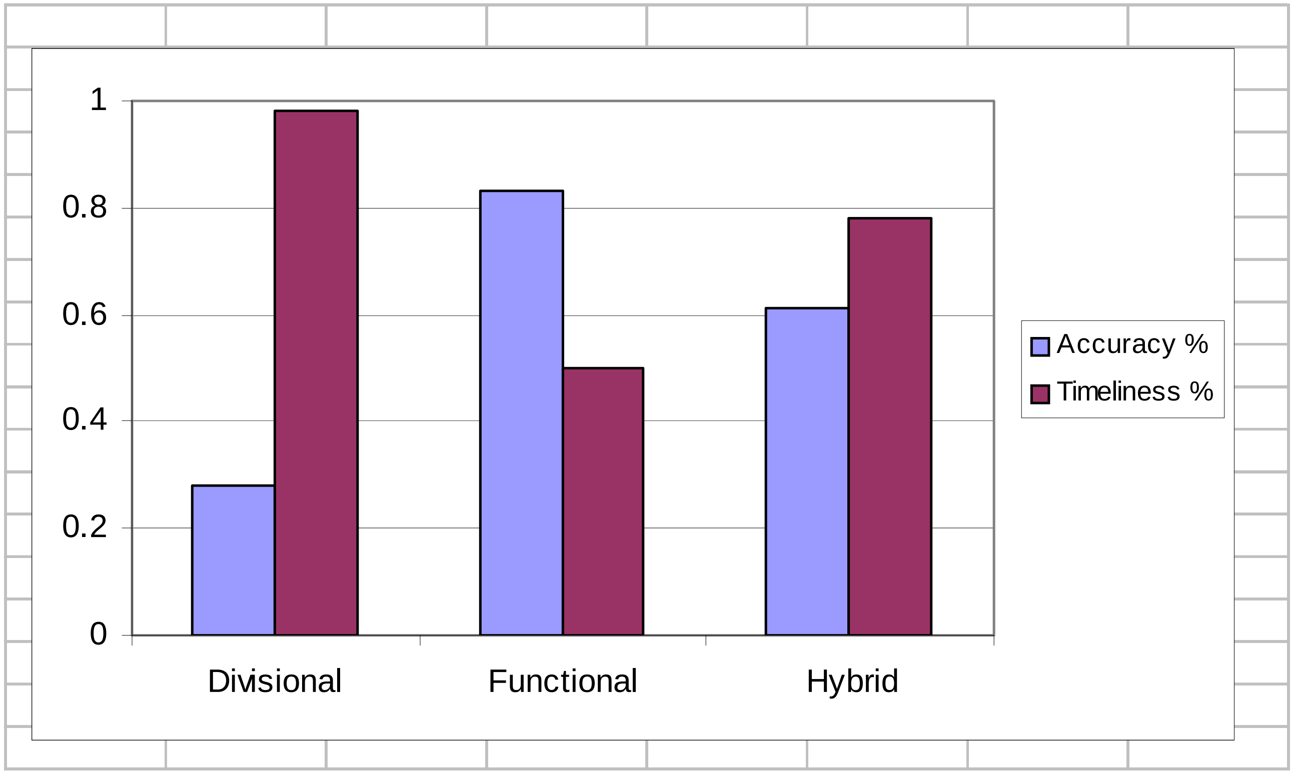
Coalition Performance

- Timeliness expresses the coalition's ability to respond to an incoming task within an allotted time.
  - The allotted time is the time interval over which the output produced by the coalition is effective in its environment.
- Accuracy expresses a coalition's ability to make a correct response to an incoming task.
  - The accuracy is described as an interval that contains the correct response plus or minus a margin of error within which the response is still acceptable.

Coalition Performance

- When a system performs an action on a task outside its current geographic location, the task incurs a delay.
  - Task assignments based on sectors are predicted to be timely but less accurate.
- When a system performs an action on a task without the required capability, the accuracy of the task decreases.
  - Task assignments based on system self-assessment are predicted to be accurate but less timely.

Simulation Results



Conclusions

- Task assignment strategy induces different levels in collaboration and effects coalition performance.
- Traditional schemes may not always be optimal in coalition operations.
  - Adjustments to functional assignment based on capabilities.
  - Adjustments to sector size based on troop strength.
- Investigating operational architectures resulting from task assignment strategy contributes to the larger question of designing heterogeneous command centers that can dynamically adapt over time.

Current Research

- Developing a research concept which will expand the coalition model to allow organizations to join and leave the coalition over time
  - Constraints include attributes of heterogeneity between different types of organizations
  - Dynamic structure for establishing (and disestablishing) links between the appropriate nodes of the cooperating command centers
- Scenario and Coalition Data to populate the model will be based on actual coalition experiences in Bosnia
  - Include Model Validation